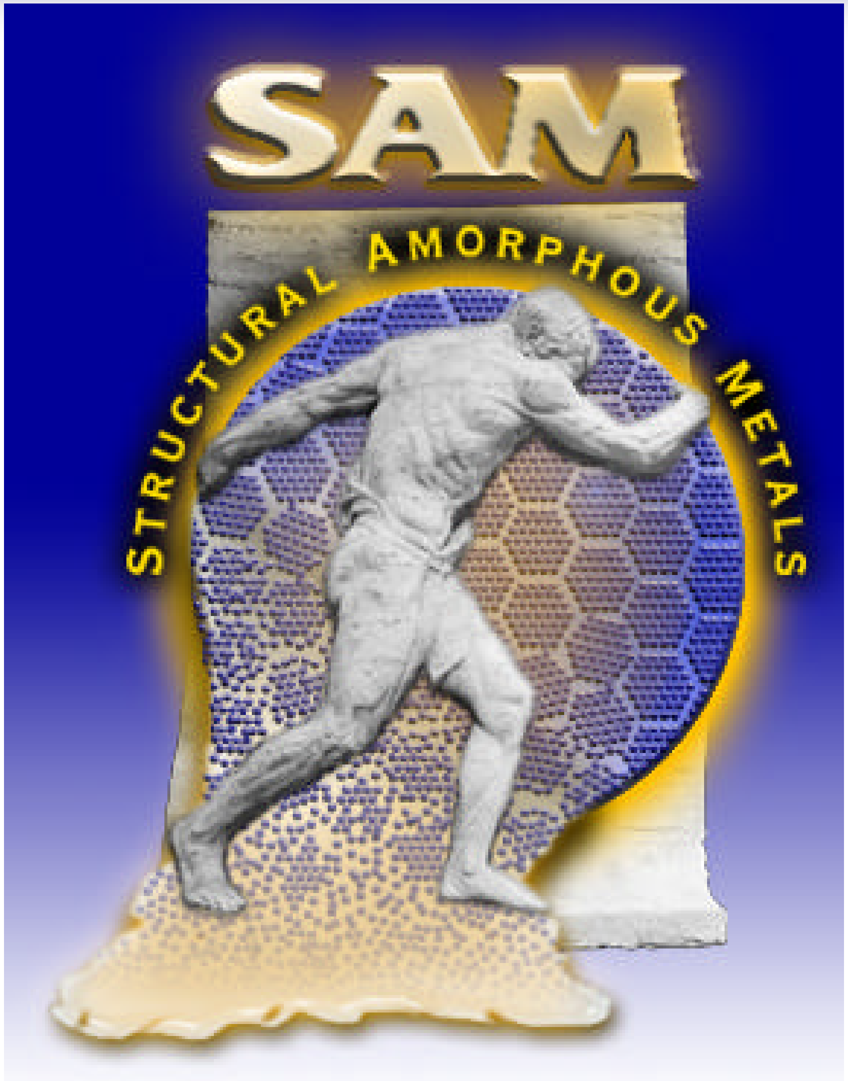

SAM
STRUCTURAL AMORPHOUS METALS

Structural Amorphous Metals (SAM)

Leo Christodoulou

DARPA/DSO

Pre-proposal Workshop

June 6, 2000

Arlington, Virginia

Agenda

• DARPA Program Overview	L. Christodoulou (DARPA)
• Possible Application Domains	
Navy	W. Messick (NSWC)
Air Force	D. Miracle (AFRL/AFOSR)
Army	R. Dowding (ARL)
• Technical Discussion Lead (45 minutes)	W. Johnson (Cal Tech)
• Participant contributions (5-10 minutes)	ALL present
• Programmatics	A. Diness
• Website demo	H. Heigele
• Questions and answers	
• Teaming interactions	As desired

Objectives of Meeting

Introduce DARPA’s interest in amorphous metals

Provide information on anticipated research thrusts, focus areas, plans and initiative structure

Illustrate potential DoD application areas

Provide some background information on the technology

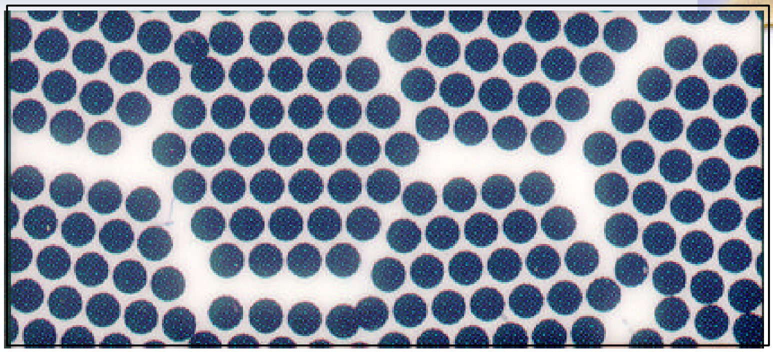
Give opportunity to community to provide input to DARPA on broad areas of interest

Provide opportunity for teaming

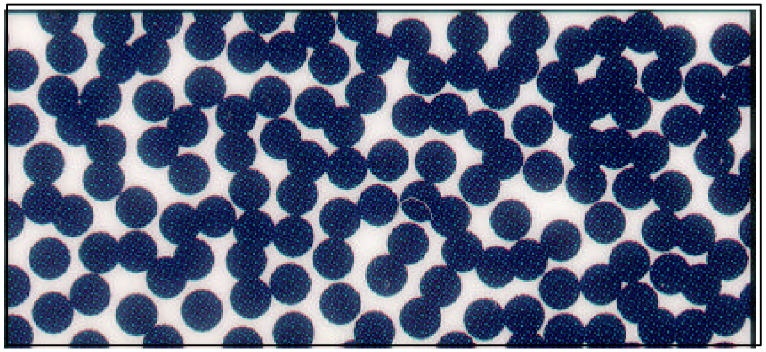
DARPA is Soliciting YOUR Ideas on Potential Program Activities

Amorphous Metals are Fundamentally Different

Crystalline (Normal) Metals
- *Long-range order*
- *Grain boundaries*



Amorphous Metals
- *NO long-range order*
- *NO grain boundaries*



Amorphous Metals Exhibit Unique Properties

Background

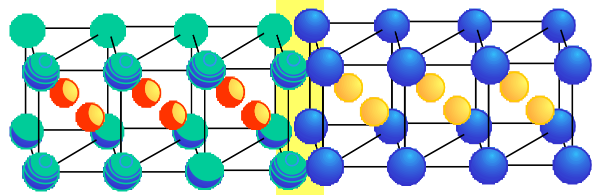
- Materials derive their properties from their "structure"

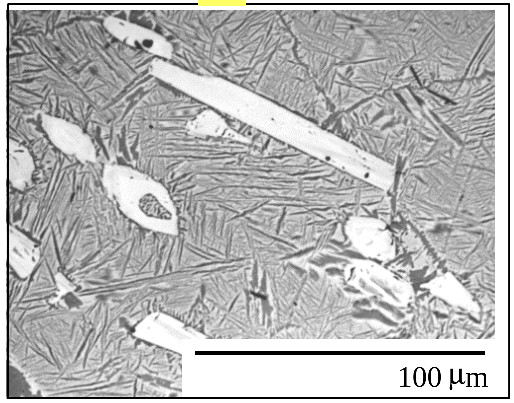
  metals, ceramics, semiconductors, magnetics, composites, etc.

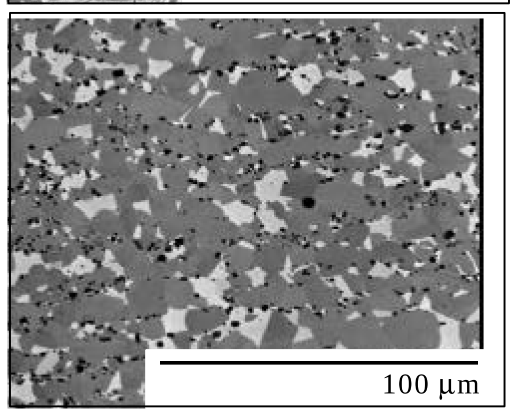
- Structure incorporates

  chemistry, scale, morphology, crystallinity, surfaces (external, internal), defects (point, line, volume), etc.

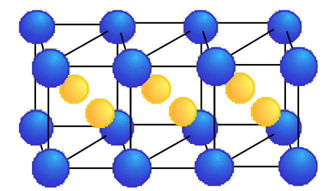
Polycrystalline

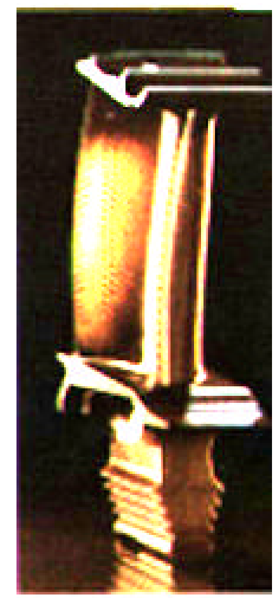






Monocrystalline





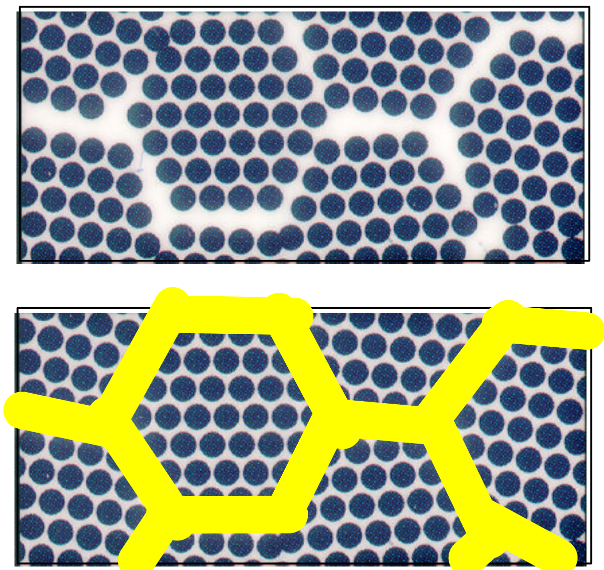
Examples:

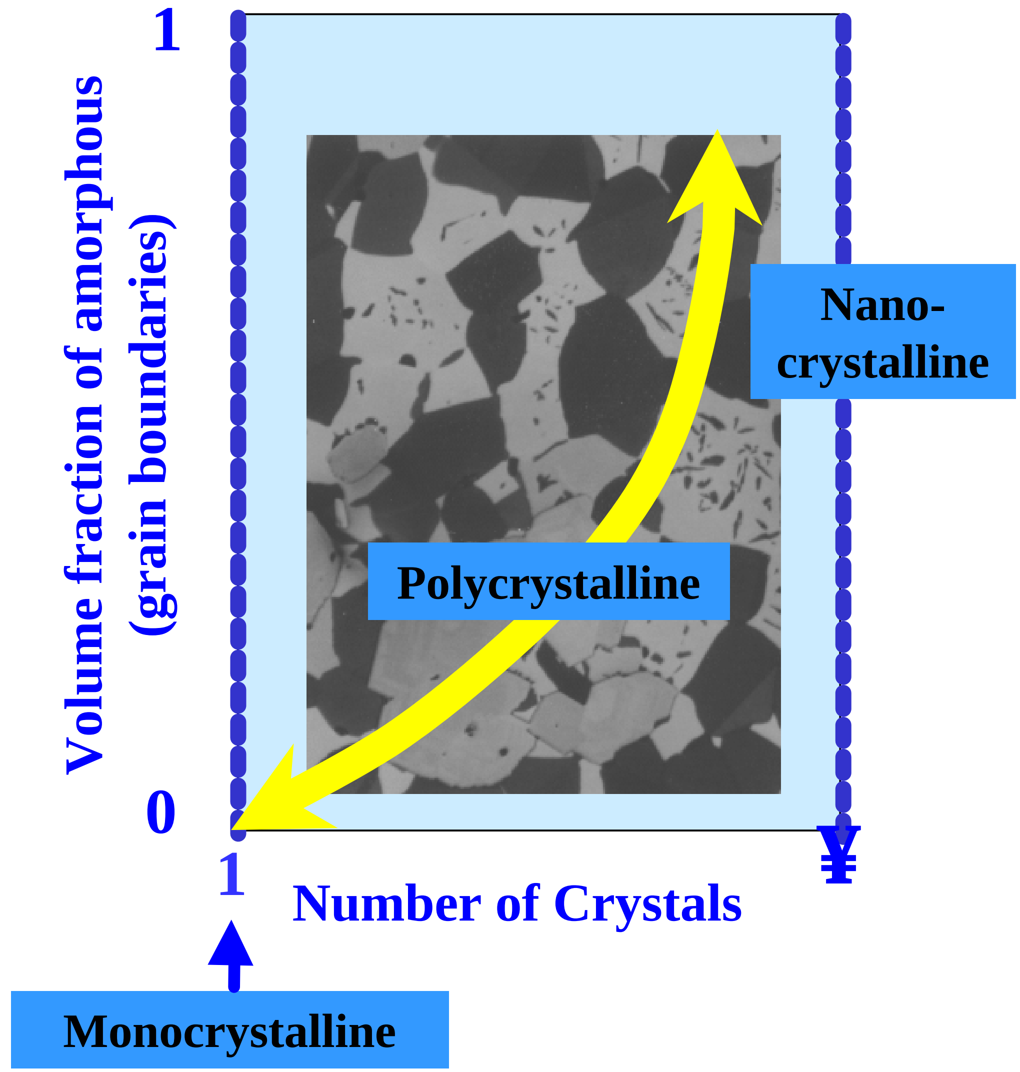
Some turbine blades

Si, Bi_2Te_3, etc.

Grain Boundaries: Crystalline Materials

Polycrystalline

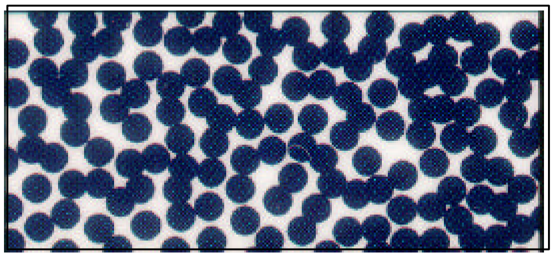


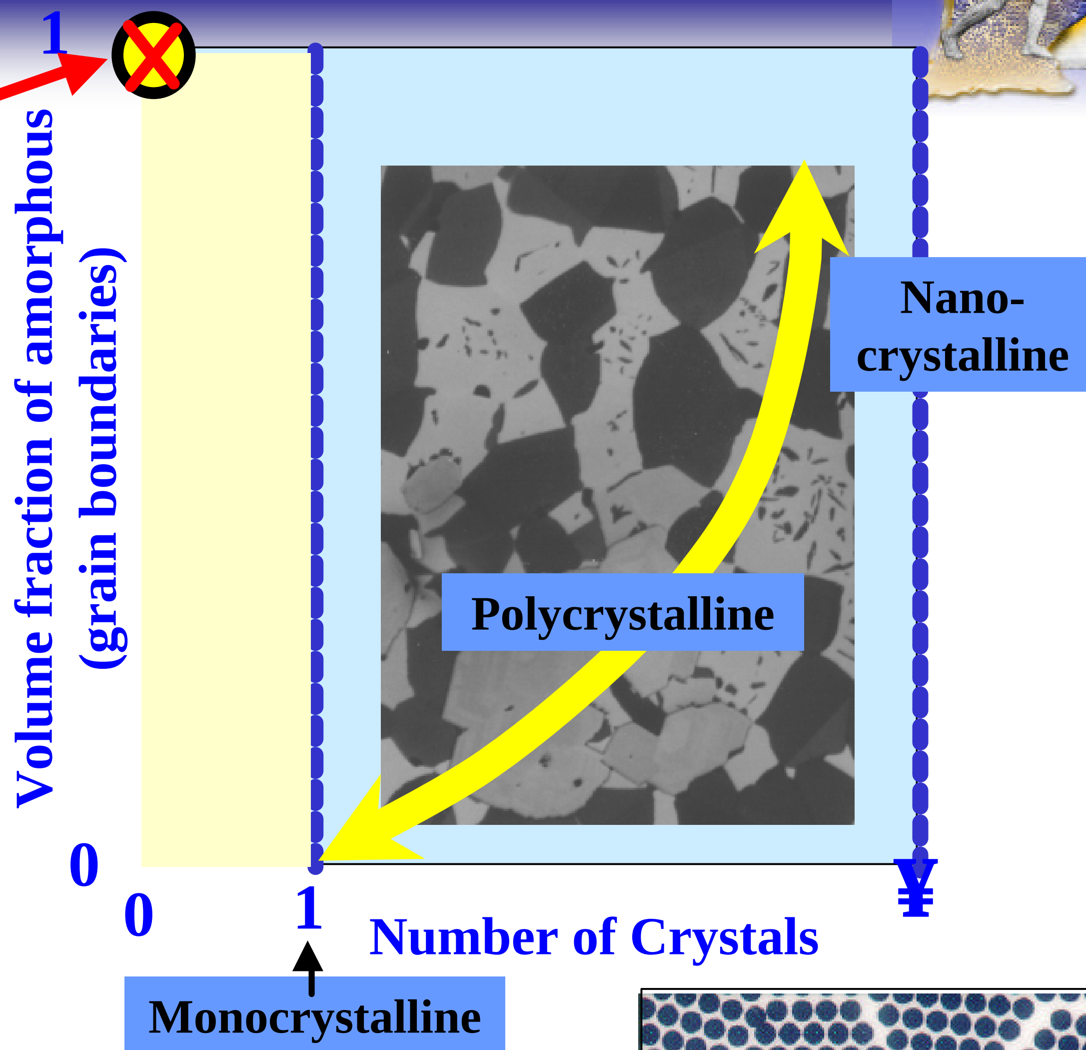


- **High angle grain boundaries can be considered as “amorphous”.**
- **Changes in grain size change the amorphous volume fraction of amorphous material**

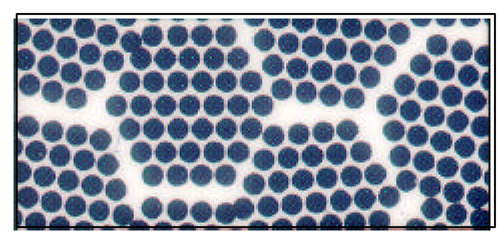
Structural Amorphous Metals Are Different

Amorphous



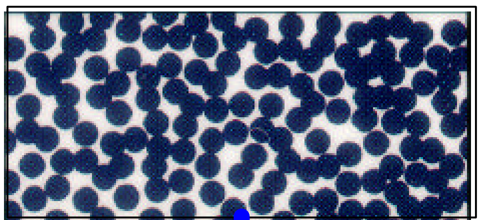


- **Amorphous Metals are NOT confined by limitations of crystalline materials**
- **A new opportunity now exists for structural materials.**

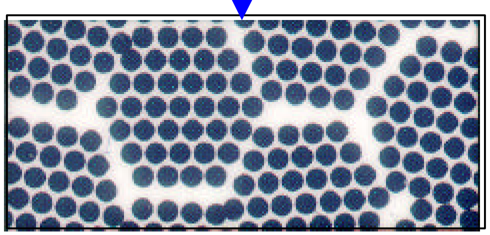


Transformations of SAM to Crystalline Offer Additional Degrees of Materials Design Freedom

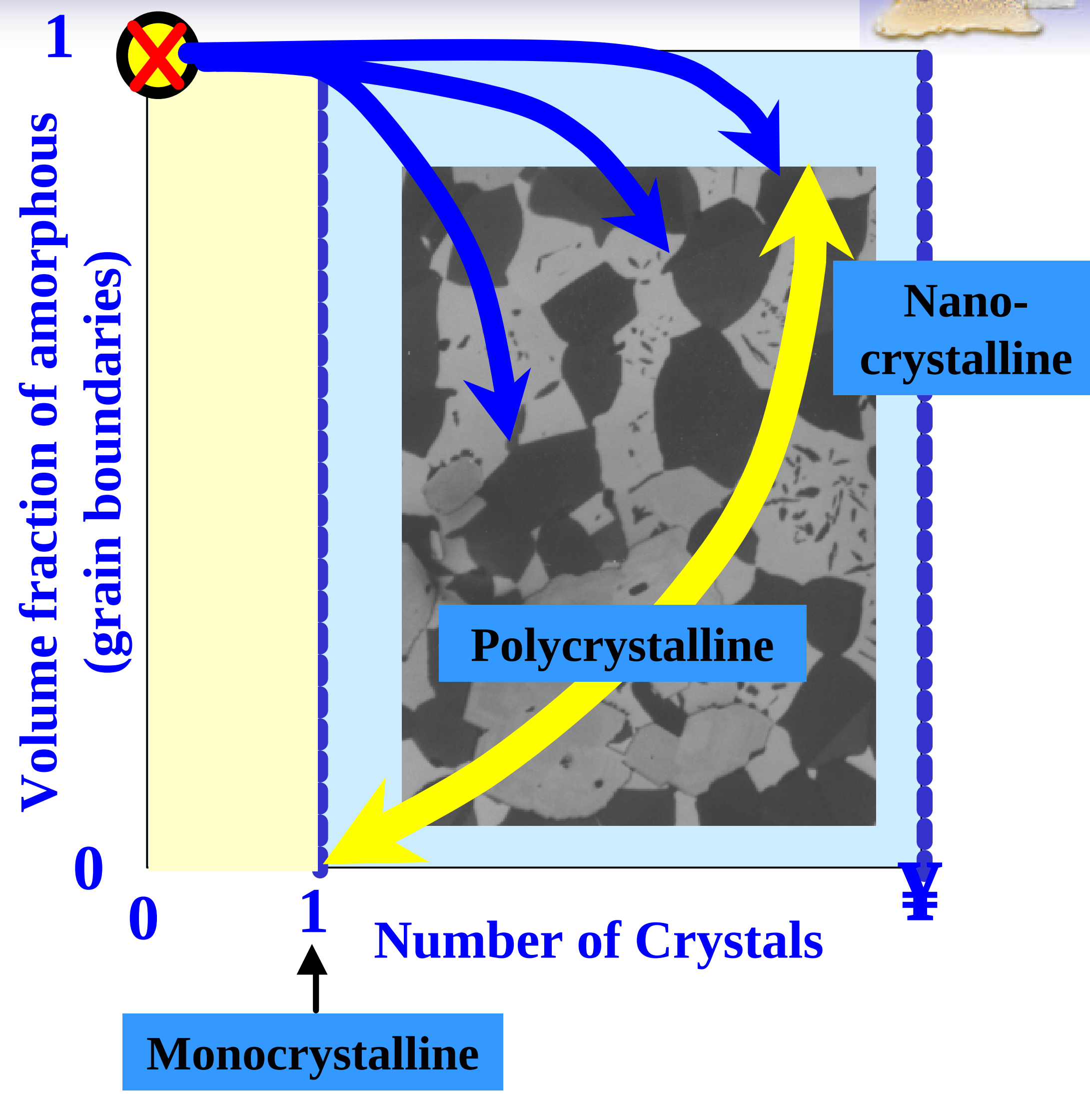
- Short-range order
- NO grain boundaries



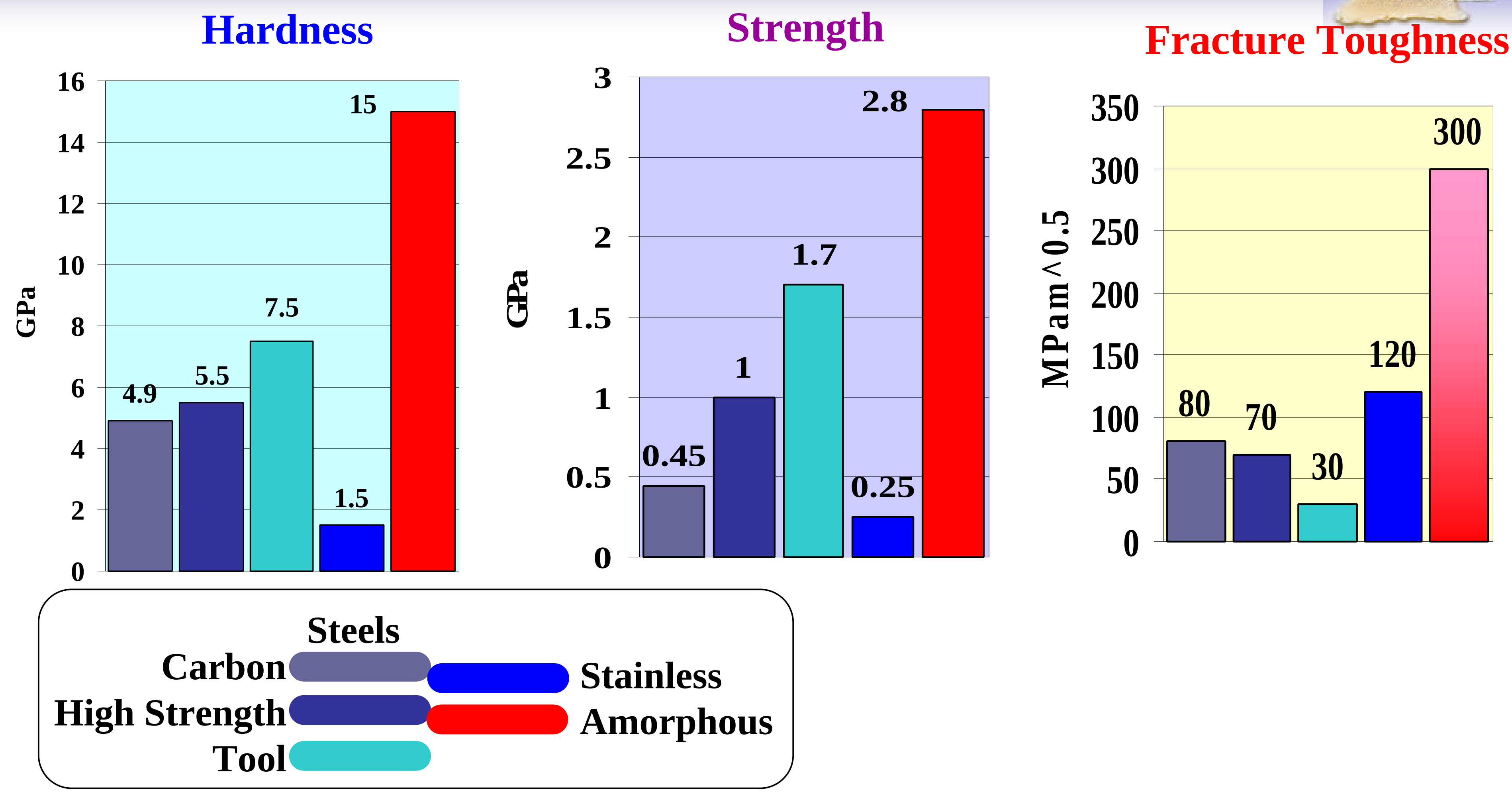
Transition path could be of **CRITICAL** importance



- Long-range order
- Grain boundaries



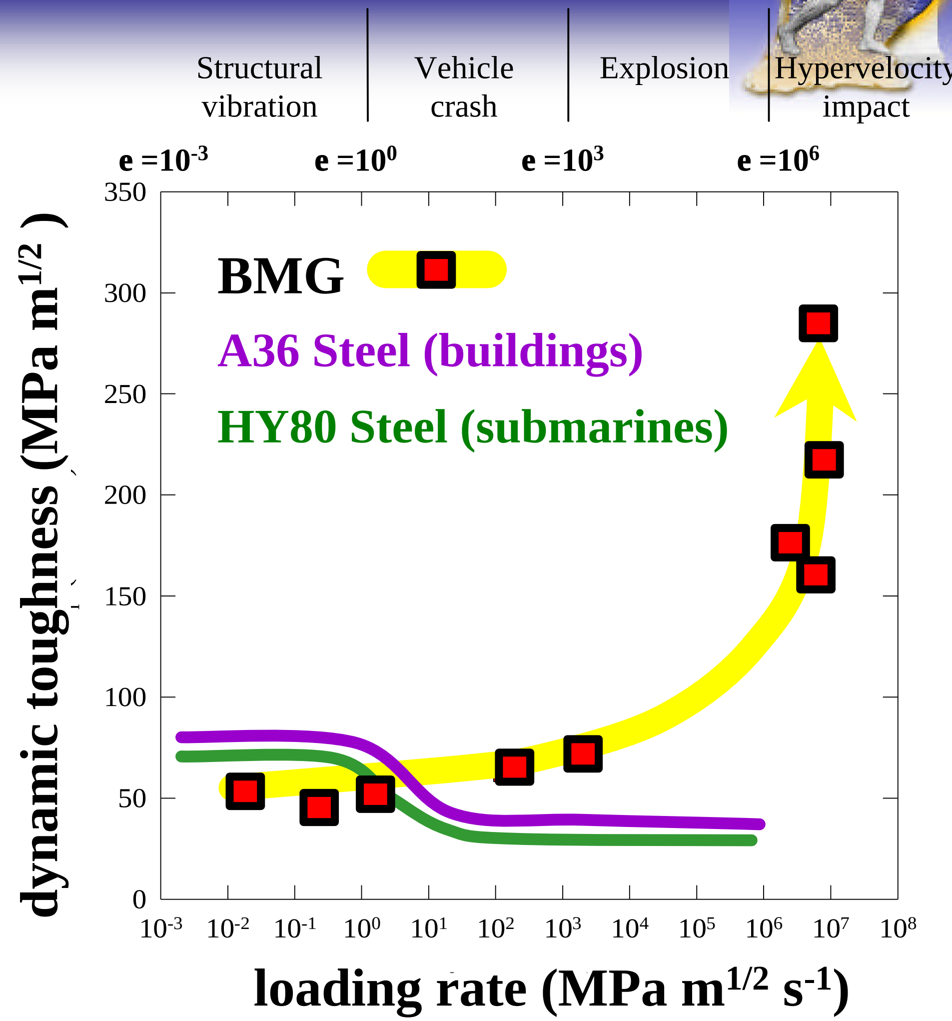
Why Amorphous Metals?



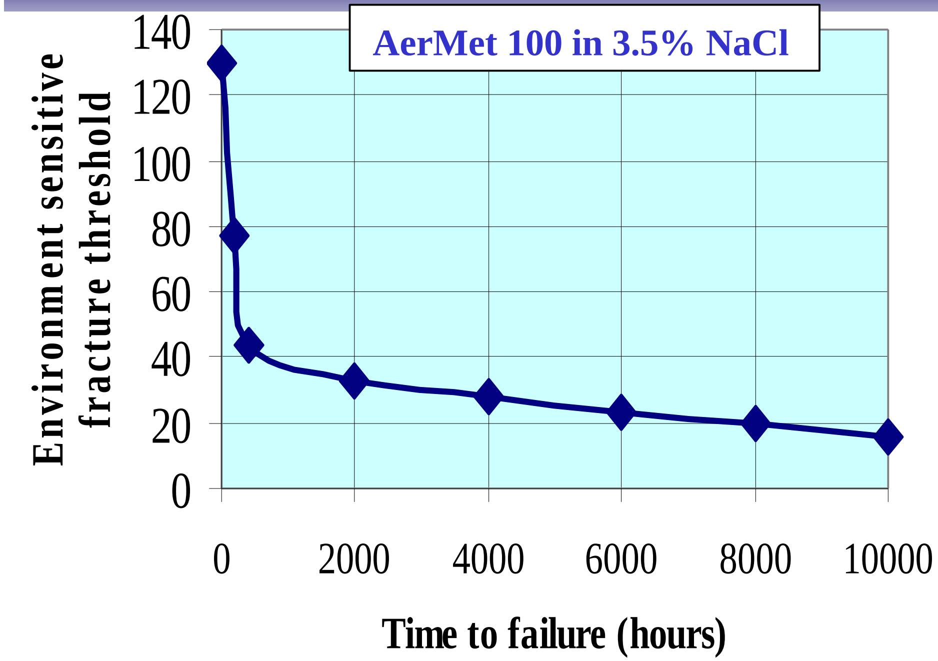
Amorphous Metals are in a Class of their Own!

Unexpected Strain Rate Response in BMG

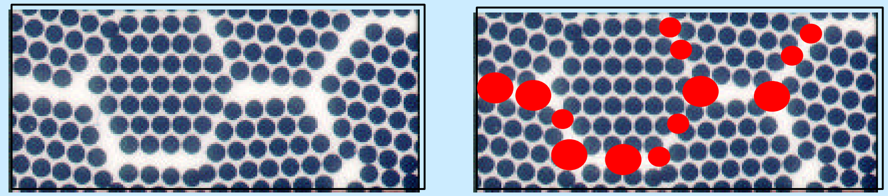
- **Dynamic toughness of BMGs is <u>EXACTLY</u> the opposite of conventional materials -- toughness increases with strain rate**
- **All conventional materials exhibit reduced toughness with increasing strain rate**
- **<u>Speculate</u> that combination of high strength, hardness and dynamic fracture behavior will translate into good ballistic/blast response**



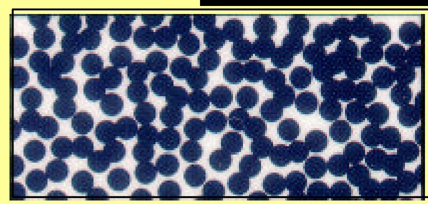
Wear and Corrosion



Crystalline Localized Corrosion



Amorphous Steel



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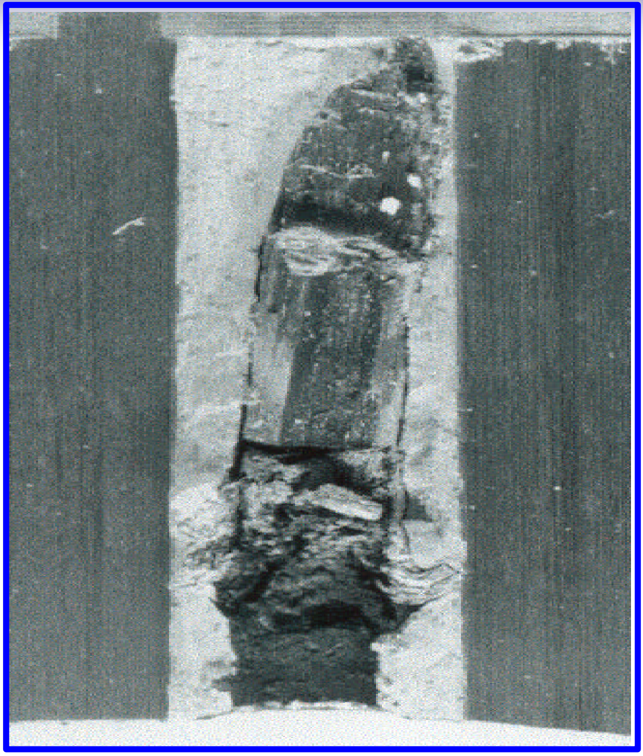
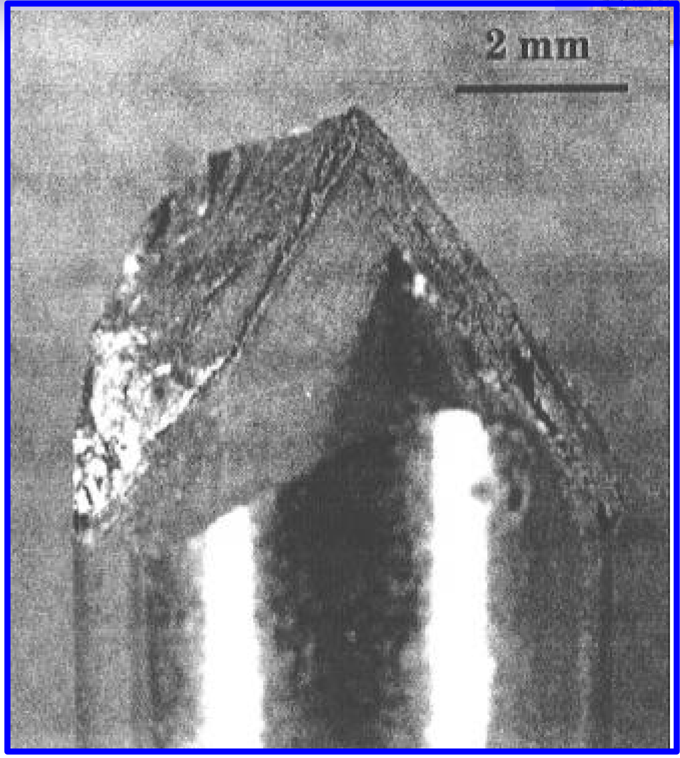
Amorphous Materials

- **Do NOT have grain boundaries (NO corrosion initiation sites)**
- **Very high wear resistance (better than Si_3N_4)**
- **Damage tolerant**

New Penetrator Materials





BMG material known to exhibit self sharpening behavior

DARPA Investment Philosophy

- **High risk, high payoff projects**
  - **Revolutionary, Enabling, Compelling**
  - **Sound “physics”**
  - **Targeted “challenge problem”**
- **“Venture capital” model**
  - **High barrier to project selection**
  - **Investment decisions quick and final**
  - **Elimination of marginal/evolutionary projects**
- **No pre-allocation of resources to specific disciplines**

Challenge Problem

Challenge Problem

- Application oriented
- Forms the focal point for targeting research effort
- Has specific technical objective(s) to meet a present or future need
- Has a specific and quantitative outcome
- Can serve as a demonstration of a broader technology impact

General Aims of DARPA

- **Establish the science for producing and using amorphous metals**

  What controls glass forming behavior?
  Can we synthesize “amorphous” alloys by design?
  What useful microstructures can be developed?
  What controls properties, especially deformation and fracture behavior?
  What are the technical scale-up issues?
  Where are the troublesome problems?
  Are there hidden problems?

- **Deliver material system with compelling performance, low cost and environmentally benign constituents in example challenge problems**

- **Involve Services and industry upfront to ensure transition**

There is a Broad Area of Activities that are Potentially Encompassed in this Initiative

- Understand mechanism(s) of formation and evolution of properties.
  - Explore composition space and synthesize materials
  - Develop models and/or tools to predict amorphous alloy formation
  - Determine useful microstructural evolution pathways from amorphous state
  - Determine mechanisms and models of deformation and fracture
  - Characterize strength, hardness, damage tolerance, corrosion resistance, wear, friction, etc.
- Develop fabrication and processing methodologies
  - Production methodologies (bulk processes only)
  - Sheet, wrought products, castings and net shape products
  - Joining techniques
  - Aim for low cost processes and environmentally benign materials
- Deliver material systems and facilitate transition
  - Target specific challenge problems
  - Show feasibility and take materials through to demonstration items in the application environment
  - Define requirements for scale-up

These are possible activities that have been identified. Not exclusive or prescriptive!!!

Potential Overall Initiative Structure

- **Most likely three focal areas/teams (e.g., Fe, Al, Refractory)**
- **University activities: MURI-like (may be jointly funded by other Agencies)**
- **Each focal area to be industry-led (can include universities, Government labs, overseas institutions)**
- **DoD Agency collaborator/DARPA agent for each focal area**
- **Limit to bulk material systems of greatest impact**

  Not a "gram quantity" material program
- **Program will aim to be "balanced"**

Anticipated Program (1)

Total anticipated funds: Approx. $30M

Cost share: Meaningful cost share DESIRED but not required

Collaborating Agencies:
ONR/NSWC
ARO/ARL/ARDEC
AFOSR/AFML

Transition: Close interaction with potential user Agency desired. Transition plan an evaluation factor

Instrument type: Any suitable (Contracts, Grants,
other transactions, etc.)

Anticipated Program (2)

Government Labs: DoD labs CANNOT respond directly to BAA. As subs/team members OK
DOE Labs can lead under special arrangements

Overseas organizations: Permitted (ITAR and other regulations apply)

Agency Co-ordination: DARPA desires to co-ordinate activities with other Government Agencies; ONR, ARO, AFOSR, NSF, DOE, DOC

Program duration: 3 years

Deliverables: Material systems, models, reports, papers, final transition plan, production/ commercialization plan

Anticipated Program (3)

Meetings:	**Joint technical meetings between all teams Program reviews may be separate**
Coordination:	**Industry teams and "MURI" team to collaborate. Industry team to provide input, feedback to reports and materials to University activities**
International collaboration:	**Encouraged if it makes sense. Not a "one way street". ITAR & other regulations apply**

Anticipated Program (4)

Programs contingent on availability of funds.

For any selected proposals funding beyond first year contingent on satisfactory progress as judged by DARPA.

DARPA reserves the right to fund any or none of the proposals received.

DARPA reserves the right to fund portions of any proposed effort.

DARPA may suggest teaming AFTER proposals are reviewed. Teaming is up to the parties concerned.

Cost Share

- **Desirable, but not required**
  - **- Improves "Cost Reasonableness"**
  - **- Shows commitment especially of the industry-led teams**
- **May be from any source within the team**
- **Types in order of value as cost share**
  - **- Cash**
  - **- In-kind (actually expended) services or costs**
  - **- IRAD under control of team (not a generic IRAD in a related area)**
  - **- Prior art NOT allowed**

MURI–like University Activities

- **May be jointly funded with other Agencies**
  University proposers are encouraged to contact other agencies to explore options
- **Coordinated effort among universities desired**
- **University activity to interface with all teams after selection**
  Joint reviews, reports to be circulated to all contractors, receive materials as appropriate
- **Funds can not in general be used for equipment purchases**
- **Unlikely to fund individual investigator programs**

Potential Evaluation Criteria

Technical Merit

Demonstrates understanding of the state of the art
Critical issues identified
Provides unique and sound technical approach that meets objectives
Defines a sound technical plan including materials discovery, production, fabrication, characterization, modeling

Impact and Relevance to DoD

Well chosen material system for the selected challenge problem
Likelihood to provide bulk, low cost and environmentally benign materials
Transition plan

Personnel and Facilities

Strong credentials in relevant disciplines
Computational and experimental facilities consistent with proposed effort

Cost Realism

Proposed cost commensurate with proposed effort
Cost share

Balance Across Material Systems

Evaluation criteria will be announced in the BAA

Schedule

Pre-proposal conference	**June 6th 2000**
Feedback from community	**June 6th – 12th 2000**
Release of BAA (estimated)	**June 20th 2000**
Proposals due (estimated)	**Mid September 2000**
Notification of winners (estimated)	**Late October 2000**
Contract negotiations start (estimated)	**Early November 2000**

Communications

- **Web site:** www.sainc.com/darpa/sam**;**
  can be linked from DARPA/DSO
- **Check FAQs BEFORE before making contact**
- **All questions to be submitted via fax (703 696 3999) or via the web site (www.sainc.com/darpa/sam)**
- **NO telephone calls**
- **Answers will be posted on the Web site**
- **All charts (used on June 6, 2000) will be available on the web site**

Outputs Expected

- Establish the science for producing and using amorphous metals
- Deliver material system with compelling performance, low cost and environmentally benign constituents in example challenge problems
- Involve Services and industry upfront to ensure transition